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PAYLOAD INSTRUMENTATION FOR
PROBING ROCKETS

R.W. EBACHER

Wentworth Institute of Technology
550 Huntington Avenue
Boston, Massachusetts 02115

December 1979

Final Report
April 1976 - March 1979

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: AFGL-TR-80-0027	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): PAYLOAD INSTRUMENTATION FOR PROBING ROCKETS.		5. TYPE OF REPORT & PERIOD COVERED: Final Report, April 1976 – March 1979
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): R.W. Ebacher		8. CONTRACT OR GRANT NUMBER(s): F19628-76-C-0211
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Wentworth Institute of Technology, 550 Huntington Avenue, Boston, Massachusetts, 02115.		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62101F 765904AK
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Geophysics Laboratory, Hanscom AFB, Massachusetts 01731 Monitor/Joseph F. Geary, Jr./LCR		12. REPORT DATE: December 1979
		13. NUMBER OF PAGES: 15
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report): Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Upper atmospheric region
Probing rocket payload systems
Universal Time Delay
Automatic Test System
Rocket-Borne IR Sensor Deployment System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Under Contract No. F19628-76-C-0211, personnel, facilities, services and materials were provided for the design, development, fabrication, assembly, installation and testing of electro-mechanical instrumentation comprising the payloads utilized in aerospace vehicles flown by the Aerospace Instrumentation Division of the Air Force Geophysics Laboratory, Hanscom Field, Bedford, Massachusetts as a part of the upper atmosphere and astronomical research program being conducted by the U.S. Air Force.

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Special devices such as a field programmable digital timer and low cost vibration recorder suitable for general use in sounding rocket-borne sensing payloads were developed. Also developed was a control system to focus a cryogenically cooled infrared sensing instrument on a particular star.

This contract also entailed the design, fabrication, assembly and testing of instruments for the remote operation and monitoring of the rocketborne apparatus from a blockhouse along with recovery and retesting of certain instruments.

Provision was made for the preparation and reproduction of all necessary mechanical detail and assembly drawings and circuitry schematics, as well as for participation in the pre-flight, flight and post-flight field operations associated with the assembly, preparation and launching of the probing vehicles at the various launch sites selected by the Air Force Geophysics Laboratory for the conducting of rocket-borne experiments.

WENTWORTH INSTITUTE OF TECHNOLOGY

Final Report

Contract No. F19628-76-C-0211

I. INTRODUCTION

Contract No. F19628-76-C-0211 was initiated with Wentworth Institute on 1 April, 1976 by the Air Force Geophysics Laboratories (AFGL), Hanscom Air Force Base, Bedford, Massachusetts, for participation in work on one of the many and varied phases of the Upper Atmosphere Research Program being conducted by the Air Force Systems Command of the United States Air Force. Its three-year period of performance was completed on 31 March, 1979. It represented essentially, a successor to Contract No. F19628-73-C-0232 which had been in existence for substantially the same requirements and objectives during the period from 1 April 1973 to 31 March 1976.

II. SCOPE

The objective of the Upper Atmosphere Research Program is the acquisition of knowledge of the physical and chemical properties and phenomena of the vitally important upper atmospheric and inner space regions by experimentation carried on with instrumentation installed in and borne aloft by rockets, statellites and balloons.

As a part of that basic objective, this contract - which was carried on specifically with the Aerospace Instrumentation Division of AFGL, and more particularly, with the Sounding Rocket Branch of the Aerospace Division - stipulated that Wentworth Institute provide the necessary personnel, facilities, services and materials in connection with the fab-

rication and installation of experiments in suitable vehicles as designated by that Division. Basically, this included such phases as the development and construction of the instrumentation racks for the accommodation of the experimental apparatus being flown in the payload section of the rockets; the positioning and bracketing of all components; the mounting of various appendages on the skin of the vehicle for sensing devices, and the design and fabrication of all supporting cables and circuitry required for the operation of the flight apparatus, per se, as well as ground-based electro-mechanical equipment essential to the support of the project involved. Also included were the fabrication and assembly of all special devices necessary for the proper functioning of the equipment peculiar to the experiment being flown in the rocket. Contract personnel were generally involved in the field operations associated with the assembly, preparation, and launching of the experimental rockets at the different sites selected by the Division. The preparation of necessary drawings, as well as graphs, charts, reports and other visual aids pertinent to rocket-borne experiments was also included in the contractual requirements.

III. DESCRIPTION OF WORK

There were certain primary considerations in this particular research program which were determined by the Air Force Geophysics Laboratory. These included such factors as the nature, purpose, scope and objectives of the experiments to be conducted, the phenomena to be investigated, the parameters to be measured, the schedules for completion of the equipment and the launching, as well as the necessary coordination and liaison between the participating agencies and contractors. In addition, the in-

terpretation, analysis, evaluation and eventual application of the diverse data obtained from the rocket borne experiments were likewise within the province of that facility and more particularly, the various Divisions and their Branches immediately concerned with the experiments. In turn, the post-analyses of the performances and functions of the rocket system, per se, were also under the jurisdiction of the Aerospace Instrumentation Division.

However, within the stipulated scope of this contract, and through close coordination and liaison with the contract monitor and the project engineers and scientists immediately concerned with the design features of the apparatus and the theoretical aspects of the experiments, respectively, services, materials and facilities were provided for each project from the preliminary discussion stages - through the designs, development, fabrication, assembly, installation and test process - to the delivery of the completed units, or, when required, to the crating and shipping of the instrumentation to the launch site specified by the cognizant division. At the launch sites, in turn, the contract personnel participated with AFGL members and representatives from other concerned agencies in the pre-flight assembly, installation and testing of the apparatus, as well as in the flight and post-flight operations.

The primary functions performed under this contract were those directly concerned with the design, layout, fabrication, assembly, installation and testing of the components comprising the payloads for the various rocket-borne experiments undertaken by the AFGL. Each of these differed in both magnitude and degree of complexity and sophistication in accordance with the nature and purpose of the basic experiment or flight objective

and in accordance with the type of rocket selected by the Division to carry aloft the experimental equipment. In those instances where the same type of rocket was utilized for the same basic study through a series of launchings conducted over an extended period of time, the steps and procedures followed in the construction of the instrumentation rack and the modification of the payload section to accommodate the scientific apparatus were essentially the same; nevertheless, even in those cases, certain changes were incorporated in succeeding assemblies in varying degrees as a result of knowledge gained from a prior firing, thus effecting a more stable and efficient performance with the ultimate aim being the acquisition of more and reliable data of a greater degree of relevancy.

Following the actual determination by the Division as to the experiment to be flown and the type of probing rocket best accommodative to carry it, a typical contractual project commenced with close coordination between the Institute's Mechanical and Electronics Sections and Division's representatives. Contractor staff members then proceed to meet the requirements of AFCL by utilizing their combined technical background and abilities as well as knowledge gained on past rocket performances relevant to the project to solve the difficult problems inherent in such an undertaking. The procedure involved producing various detail and assembly drawings required for the components and sub-systems comprising the instrumentation system and the payload. These encompassed all design features for the basic instrumentation rack, the method of installing and mounting the diverse components comprising the payload members, and the necessary details for the modification of the rocket nose cone in order to make it compatible with, and accommodative for, the experimental equipment per se, as well as the various

schematics and diagrams required for the circuitry for the experiment. After the checking and subsequent reproduction of the drawings, the fabrication and assembly was initiated. Concurrent with this action was the placement of orders for the procurement of the necessary stock, hardware, and commercial mechanical and electrical components specified for the construction and assembly processes. As these phases proceeded, periodic discussions were held between Laboratory representatives and contract personnel not only with regard to the overall progress of the project but also in connection with any possible assembly difficulties being encountered or modifications of design often required when newly-fabricated parts are being assembled for the first time.

The nature of the process was such that in many instances certain of the electronics work could not be commenced until portions of the basic payload instrumentation rack and other mechanical components had been completed by the Missile Laboratory; on the other hand, wherever possible, sub-assemblies were prepared as soon as the circuitry requirements and specifications were determined. Cables and harnesses were also prepared in advance whenever possible. After the assembly of the mechanical and electrical phases, the equipment was subjected to a series of tests and checks by Laboratory and contract personnel; certain of these tests were performed at the Institute's facilities, while others, because of the requirement of special equipment, were conducted at the Air Force Geophysics Laboratory, or available compatible government/ commercial facilities. Upon the completion of these tests and after the incorporation of any modifications, both mechanical and electrical, which were deemed necessary as a result of the checks the equipment was packed in appropriately-assembled boxes and then shipped to the launch site desig-

nated by the Aerospace Instrumentation Division.

Generally at least one member of the contract group travelled to the launch site to participate in the pre-flight, flight and post-flight field operations with members of the AFGL and other concerned agencies. On some occasions, two or three members, in combinations from the Design Section and the Electronics Section, would take part in the launch operations, depending upon the complexity of the rocket-borne experiment involved and the scope of the duties and activities delineated for completion at the site itself.

In view of the fact that the definitive data and pertinent information from the various related sequential steps of the projects, from the planning stages through the operating and concluding steps were progressively accumulated, recorded, evaluated and utilized by the AFGL, this report will constitute a brief summary of major projects or tasks indicative of the basic objectives of the contract, rather than a detailed description of the many and varied processes performed in the Design Section, Missile Laboratory and the Electronics Section. More detail on any of the projects described herein as well as more minor projects, in terms of Wentworth's participation in them, can be found in the Quarterly Reports (Nos. 1 - 11) and Scientific Reports (Nos. 1-2) published under Contract No. F19628-76-C-0211.

Wentworth Institute of Technology took part in seven launches during the contract period. Major projects launched included Project A35.191-4, Project A24.7S2-1 (Project SPICE), Project IC 730.09-1, Project A31.603 (Project PIBS), Project A03.604 (Laser payload), Project A07.712-2 (Seven-inch-sphere) and Project A12.9A1 (Ten inch-sphere, Red Lakes, Ontario).

During the middle of 1976, the payload and associated ground support

equipment for rocket A35.191-4 was packaged for shipment to White Sands Missile Range, New Mexico. The equipment for the experiment included the following: nose cone with ELE Sensor, ACS pneumatics and support systems, and pitch, yaw and roll jets; telemetry with UHF (S-Band) PCM/FM telemetry link; ACS with gyros, an associated support system and unbilical, sensor extension with ELE sensor, 1st and 2nd separation, and Yo-Yo despin; sustainer with range safety command receiver and quadra loop antennas and the tail section with distribution box and squib operated oxidizer and fuel cut-off valves. The objective of this launch, which took place on 3 August, was the investigation of natural radiation of the Earth's limb which is emitted by the atmosphere, as well as the investigation of infrared Zodiacal light near the sun. Two contract members were at the site from 18 July to 5 August for the launch operations.

Project A24.7S2-1 (SPICE I) was worked on throughout the contract period, SPICE stands for Survey Program of Infrared Celestial Experiments. The purpose of the program is to map existing sources of infrared radiation in space. For this purpose a cryogenically cooled infrared sensing instrument must be controlled so that it can take data through essentially all the solid angle around the rocket.

The control system concept used in this project was originally used in the Hi-Star and Hi-Hi-Star South payloads. The successful performance of these payloads in a previous contract period formed the basis for using this concept in Project SPICE I. The system includes a very rigid structure housing the sensor. This was increased in size by a factor of ten relative to the previous system. A gimbal system, gimbal drive assembly consisting of a gear box, function cam, shaft encoder and precision pot, gimbal brake

assembly with power to engage a friction disc type brake and LCU package are also components of the control system.

The modifications that were incorporated in this control system have produced a more versatile and controllable system. A large variety of deployment programs may now be implemented without major hardware changes. Added features such as the bi-directional step program, programmable step angle and selectable offset angle have increased the systems versatility while increased detection and braking capability combined with voltage wave shaping have improved system control.

Three contract members travelled to White Sands Missile Range, New Mexico, in January 1979. Project SPICE I was launched on 27 January, at 11:00 p.m. Unfortunately the sensor door did not unlatch and the parachute ripped during re-entry.

In February 1979, the door latch system was examined to determine the cause of failure. Much time was spent at AFGL testing the system. Tests were completed on 1 March. A separate report on the failure is being prepared. No data were obtained and no knowledge of the efficiency and accuracy of the control system was gained. The system is planned to be used in future projects. Work is proceeding on its next use in Project A24.7S2-2 (Project FIRSSE) which is underway as this contract period expires.

For Project IC 730.09-1 one contract member travelled to Utah State University, Logan, Utah in October, 1977 in connection with the mechanical integration and testing. A gap above the nose cone release was corrected. The same contract member stayed at the Poker Flat Research Range, Alaska, from 24 October to 14 November. The payload was launched on 12 November, 1977.

Project A31.603 (PIBS) is another project which was launched during

this period. PIBS stands for the Positive Ion Beam System. The instrumentation section includes the following components: instrumentation rack, including brackets, longerons and decks, instrumentation probe booms, blow-off door, blow-off door mechanisms, boom housings, access door and stiffeners, mirror slide mechanism, and instrumentation skin housing with all skin cut-outs for probes and access openings. The standard parachute recovery section was modified to include an air stroke actuator, a power energy source device to obtain greater separation velocity. The electron gun cap puller was modified.

Two contract members travelled to White Sands Missile Range, in the early part of 1978 to participate in the preparation and launch activities. The telemetry data indicated that one boom didn't extend to its full length. A problem was encountered in the installation and removal of the vacuum system to the payload. One contract member had to power and monitor Wentworth's part of the payload.

Project A24.7S1-1 (IRBS) is a project that is still in progress at the end of this contract. IRBS stands for Infrared Background Sensor. Some items under construction for this project are an on-gimbal electronic box, door and hinge mechanism for the star-tracker and sun sensor, baffle for the star-tracker, and payload handling fixture. Other components include a skin stiffener for the star-mapper and sun sensor, forward end sealing ring and clamp, star tracker baffle, payload handling and payload filtering system.

Also in progress is project ZIP (Zodiacal Infrared Project). The sensor for ZIP is an infrared detector array which must be cooled cryogenically with a liquid helium dewar. Main components are an optical telescope to align the detector array, vacuum vessel, dewar and low temperature supporting devices.

Since a certain temperature must be maintained for the duration of a rocket flight a model sensor was built in order to measure the hold time of the liquid helium dewar. This flight qualified components such as a cold plate, support ring, radiation shields, vent tube, multilayer insulation, vacuum pump out valve, vent heater connector, pressure relief valve, manual ball valve, burst disc and low temperature insulating trunnion support. The telescope was replaced by a telescope mass mock-up. Many refinements in the system had to be made before a sufficient hold time was achieved.

After the model sensor was successfully tested, work began on the fabrication of the two actual ZIP sensors which were originally scheduled to be launched from Woomera, South Australia. These sensors which are presently incomplete are now scheduled to be launched from White Sands Missile Range, New Mexico.

Several projects completed by Wentworth Institute of Technology have general applicability to various payloads. Two of these projects, The Six Switch Digital Timer and The Rocket-Borne Vibration Recorder (Project ROVIR) will be discussed here.

The ZIP, SPICE and IRBS projects programming requirements could not be satisfied by using previously available timers. A new timer was designed under this contract during 1977 and 1978.

The design objectives were as follows: The timer had to withstand the severe vibration and shock levels created by solid rocket motors and be accurate to 1% over a temperature range of $-40^{O}F$ to $140^{O}F$ with a minimum timing range of 15 minutes. The output had to consist of six independently programmed SPDT switches capable of handling a current of 1 amp. It was also desired that the timer could be operated as a slave to a

second unit thus extending to twelve the number of outputs. Another objective was to provide some means of inhibiting the functioning at any one output when the occasion demands. The unit had to be capable of being controlled and monitored during operational checks of the payload as well as in the launch configuration and needed to be easily programmable in the field.

Several design concepts were considered, three of which were explored through to the breadboard stage. The design approach selected was a spin-off of an earlier design used successfully by the Hi-Star and Hi-Hi-Star projects. This was expanded and modified by switching from TTL to CMOS Electronics.

Eventually a Digital Timer Model WI 206 of dimensions 1 7/8" by 4 7/8" by 5 5/8" weighing 1 3/4 pounds was developed. The timer design used two circuit boards connected by 16 pin DIP ribbon cable connectors. Special patterns on the p.c. board allowed the use of Augat #8136-651 P2 two pin connectors to jumper the inhibit lead of each output through to the Cannon DCC-37P Connector. These inhibit leads are brought out only if they are to be used. Another P.C. pattern is used to select one of the five clock frequencies to be used by the timer. A label fixed to the top cover plate provides space to note the installation of these jumpers as well as providing brief instructions for programming the timer.

The three basic elements in the design are a counter, a programming device and a NAND gate. A NAND gate output switches from high to low when all its inputs are high. The NAND gate inputs 1,2,3 and 4 are tied respectively to counter outputs 2^0, 2^1, 2^2, 2^3 through the programming device represented here as a closed SPST switch. The result is a halving of the output signal from one signal to the next. Each output is labelled with

a value, in powers of two, that represents the number of clock periods contained within one half cycle of its output. The time out desired is obtained by summing together these numbers of clock periods represented by each counter output.

The timer is reset and started by a Teledyne 411D-265 relay. Programming the timer is accomplished by plugging two pin jumpers into appropriate sockets.

The Digital Timer Model WI 206 satisfied the requirements of the SPICE, IRBS and ZIP programs. Its programming ease and flexibility make it a likely candidate for use in most forseeable sounding rocket programs.

As part of the contract is was required that an inexpensive rocket borne vibration recorder (Project ROVIR) be developed. In March 1976, Wentworth Institute of Technology was asked by AFGL's Aerospace Instrumentation Branch to design and build a suitable low cost system.

A four channel recorder was required, three to record the three axis of vibration with 10mv/g sensitivity and one for synchronization. It was to operate between $-40^{\circ}F$ and $140^{\circ}F$ and withstand certain vibration and shock levels. The vibration recorder was to be controlled from the block house prior to launch. Block house controls would be necessary to power and monitor the operation of the system. Several inexpensive cassette type tape recorders were evaluated in an attempt to find one suitable for use in sounding rockets. The one selected was modified and tested (unsuccessfully) before a change in program requirements deleted the on board recording requirement.

The transducer is of prime importance to the system, its sensitivity and output characteristic had to be defined for the remainder of the system. A Bolt, Beranek and Newman Inc. (BBN) transducer was selected. It

has several favorable characteristics; internal electronics, over voltage protection, both from large transient from the piezoelectric crystal and from the output lead, immunity from 120V 60Hz and a favorable price.

An amplifier with a gain of ten was designed and built using a 741 general purpose operational amplifier. The current source and buffer amplifier were mounted in the same module. The compressor gain corner was set so that low level vibration would have the most sensitivity.

After these units were built, they were calibrated beginning in June 1977. The vibration facilities at AFGL were used to excite the BBN transducer. By using the analysis portion of the Time Data Vibration/Shock Control and Analysis Computer System the calibration was completed after many necessary tests and adjustments were made. The tape transport for on board recording requires further evaluation. The system using telemetry was flown in August 1977.